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Improving Energy Efficiency in electricity networks

Addressing Network losses & EU regulations under Article 15 (2) (a) of the Energy Efficiency Directive

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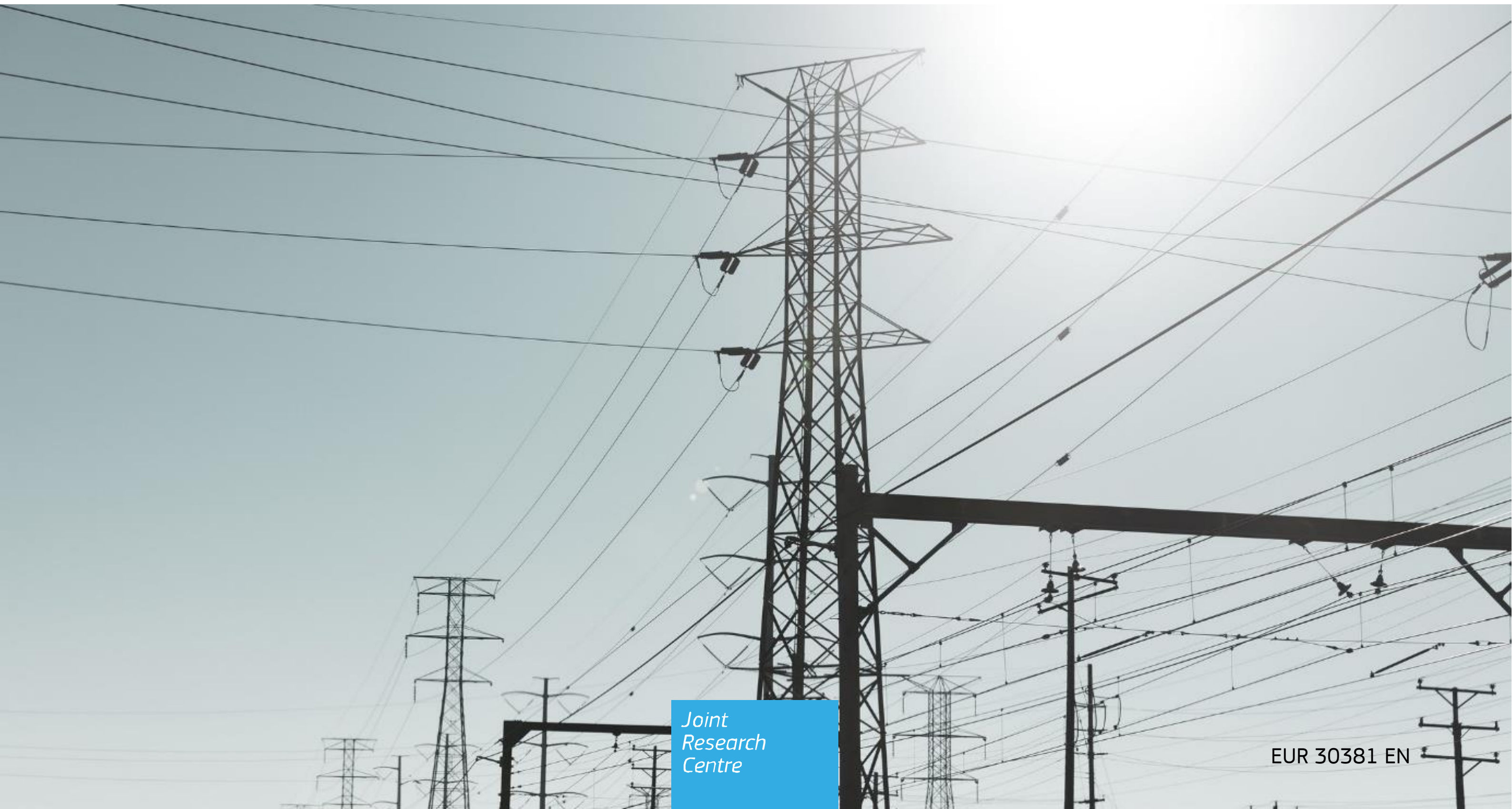

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Abstract

This report focuses on the energy efficiency of electricity distribution networks mainly from the perspective of network losses. As proposed in Article 15 of the revised Energy Efficiency Directive, the European Commission after consulting relevant stakeholders, should prepare a common methodology in order to encourage network operators to reduce losses, implement a cost-efficient and energy efficient infrastructure investment programme and properly account for the energy efficiency and flexibility of the grid. This two-part report focuses on the status of regulatory policies in the EU-28 and recommendations that can be followed by the Member States in order to improve their grid efficiency.

This first part of the report focuses on the electricity grids, with the interaction between regulation and network losses being conceptually analysed with the presently available regulation schemes and a survey on some research proposal being presented. After a brief introduction on the main standing-points of the EU framework, a comparative analysis of the regulation in EU member states is outlined. The "players' perspective" in terms of the opinion of crucial EU stakeholders and leading experts in EU are assessed thought a set of interviews of which the outcomes are presented. Finally, some recommendations for Member States and conclusions are drawn.

1 INTRODUCTION: THE EU ENERGY EFFICIENCY DIRECTIVE AND THE ROLE OF DSOs AND SUPPLIERS

The Energy Efficiency Directive (EED) [1], introduced in 2012 and amended in 2018 is the key EU policy for reaching the 2020 and 2030 energy saving targets.

In this framework, Article 7 is one of the pillars. This article:

- Asks EU Member States (MS) to introduce the so-called "*Energy Efficiency Obligation Schemes*" (EEOSs). According to the EEOS, energy distributors (DSO) and/or retail energy sales companies are required to save 1.5% of the annual energy sales during the period 2014-2020, through the implementation of ad hoc measures *("Each Member State shall set up an energy efficiency obligation scheme. That scheme shall ensure that energy distributors and/or retail energy sales companies that are designated as obligated parties under paragraph 4 operating in each Member State's territory achieve a cumulative end-use energy savings target … That target shall be at least equivalent to achieving new savings each year from 1 January 2014 to 31 December 2020 of 1.5% of the annual energy sales to final customers of all energy distributors or all retail energy sales companies by volume …"*). Not necessary strictly related to the electricity network.
- Allows EU MS, as alternative option with respect to the EEOS, to set and introduce other policies, not only directed toward DSO and retailers, provided that these policies lead to equivalent energy savings. Among the alternative policies, Article 7 mentions: energy or CO_2 taxes that have the effect of reducing end-use energy consumption; financing schemes, incentives, regulations or voluntary agreements, training and education leading to the application of energy-efficient technology and able to reduce end-use energy consumption; standards aiming at improving the energy efficiency of products and services (including buildings and vehicles), except where these are already mandatory; energy labelling schemes, with the exception of those that are mandatory
- Also allows a combination of EEOS and alternative policy measures

Consequently, under Article 7 obligations for DSOs in order to enhance energy efficiency can be set by the single Member States. Currently, 14 Member States either partially or fully generated their savings through the implementation of the EEOSs (like the so-called Italian "white certificates" and the French "Energy Saving Certificates"), namely Bulgaria, Denmark, Ireland, Spain, France, Italy, Greece, Latvia, Luxembourg, Malta, Austria, Poland, Slovenia and the United Kingdom.

According to the JRC report [2] that yearly analyses the annual reports submitted by the EU MS and related to the obtained progresses with respect to the national energy efficiency targets [3], to the energy consumption trends and to the implementation of Articles 5 and 7 of the EED, in 2016 savings obtained by EEOSs represent about 41% of the total savings related to Article 7 of EED.

Under Article 7 of the EED, all the EU MS, with the exception of Belgium, Denmark, Luxembourg and Poland, implemented alternative measures with respect to EEOS.

Another key article of the EED, namely Article 15, focused on the energy efficiency of the transmission and distribution networks, and it states that the "[EU] *Member States shall ensure that network operators are incentivised to improve efficiency in infrastructure design and operation*" and that the "[EU] *Member States shall ensure that national energy regulatory authorities pay due regard to energy efficiency in carrying out the regulatory tasks specified in Directives 2009/72/EC and 2009/73/EC regarding their decisions on the operation of the gas and electricity infrastructure*". Strictly related to electricity network.

Moreover, "Member States shall ensure that an assessment is undertaken of the energy efficiency potentials of their gas and electricity infrastructure, in particular regarding transmission, distribution, load management and interoperability, and connection to energy generating installations … Concrete measures and investments are identified for the introduction of cost-effective energy efficiency improvements in the network infrastructure …" and "Member States shall ensure that network operators are incentivised to improve efficiency in infrastructure design and operation"

Focusing on electricity network (similar principles can be applied also to the gas network), according to the requirements of this article, a reduction in the level of both transmission and distribution network losses is a key requirement for reaching this energy efficiency goal.

The current report specifically focuses on electricity network losses, with reference to the need for preparing, by 31 December 2020, a common methodology aiming at encouraging "network operators to reduce losses, implement a cost-efficient and energy efficient infrastructure investment programme and properly account for the energy efficiency and flexibility of the grid", according to what stated by the 2018 amendment to Article 15 (2a).

2 THE ROLE OF REGULATION IN ENCOURAGING NETWORK LOSSES REDUCTION

According with the Council of European Energy Regulators (CEER) [4], [5], referring to the regulatory treatment of losses on electricity networks, the procurement of losses (which is the procedure implemented in each country in order to manage the way through which covering power losses), could be under the responsibility of:

- Network operators, who are obligated to purchase the electricity to cover losses in the network they operate. Average costs of losses are approved by the National Regulatory Authorities (NRAs) and used in the tariff calculation. In this case, losses are treated like any other induced or occurred imbalance. This option is used in the majority of EU Countries, like Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Finland, Germany, Hungary, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Romania, Slovenia and Sweden
- Suppliers, who buy additional energy which will be injected for compensating the losses caused by consumption of their clients. Losses are priced at the same level as the wholesale market price to supply the consumption and are treated like any other induced or occurred imbalance. The difference between estimated losses and effective losses on the network is priced at the cost of providing the balancing energy on the balancing market. This option is used in Belgium (partially, on the transmission grid), UK, Ireland, Portugal and Spain
- A mixture of the two systems is used in Greece, where generators and importers are responsible for covering transmission losses while suppliers cover distribution losses

Currently, in several European countries, the costs for losses are payed by consumers, giving system operators no incentive to reduce network losses. Proper measures should be introduced to incentivise system operators to reduce losses in their grids or at least maintain them at low levels. Moreover, different regulatory approaches could be implemented for technical and non-technical losses to facilitate the most efficient regulatory schemes

In general, losses are one of the key contributors to operational expenditures in power networks. The CEER recommended that system operators aim to find the right balance between the costs of investing in more efficient technologies and savings in the cost for losses

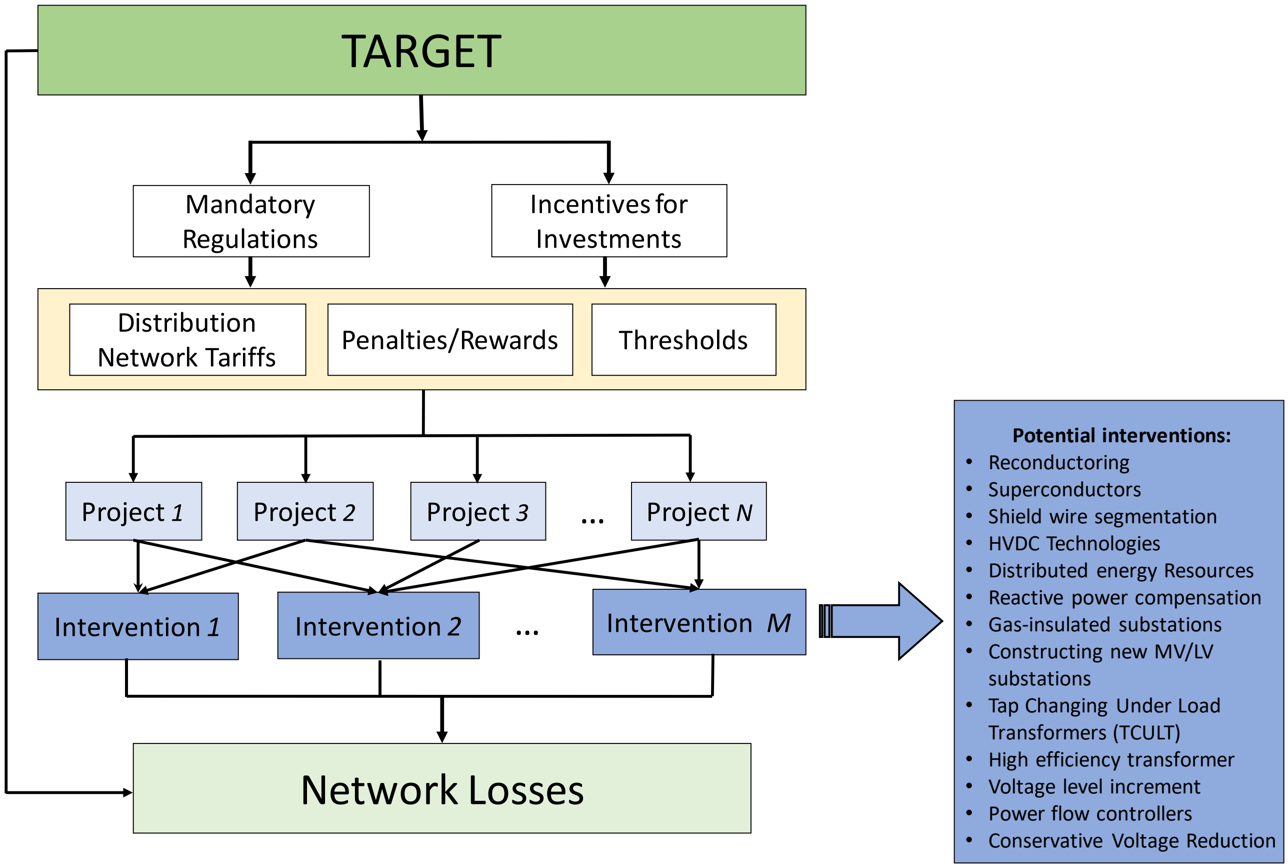
In this framework, the goal of possible incentives to be applied is to enable National Regulatory Authorities (NRAs) to ensure that TSOs and DSOs implement economically efficient operational and investment decisions aimed at limiting/reducing the level and the associated costs of the energy necessary to cover network losses

The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, presently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:

- Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)
- Allowed rate of losses to include in tariffs capped to a maximum percentage value
- Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value

A general scheme showing how regulation can affect the reduction of the network losses is represented in Figure 1 below:

Figure 1 - Impact of regulation on the reduction of network losses.



Source: JRC, 2020

3 RESEARCH PERSPECTIVES

Ortega et.al. in [6] discussed the main approaches used for recovering distribution network costs and highlighted the weaknesses of each method. Then they proposed a new tariff design based on the cost causation principle. According to [4], distribution tariff designs are separated in two parts:

1) determination of total allowed revenue by distribution companies, and
2) allocation of this revenue requirement among network users.

Accordingly, the focus of [6] is on the second part, i.e. to allocate the distribution utility revenues requirements among all customers in an optimal manner. The proposed tariff allocation mechanism is based on game theory, considering the customers' utility function to remain constant. Assuming demand to be inelastic, the optimum network to be designed is the one leading to minimum cost, and each customer should pay the costs that he/she causes to the system, depending on its geographical location and peak demand and energy in each time-of-use block. Under this approach, each customer is expected to minimize his/her costs which contributes in the costs caused to the system, so behaves such as to minimize system costs.

The integration of Distribute generators (DGs) into the networks pose challenges for distribution system operators (DSOs) and their regulations. In terms of DSO's expenditures, the integration of DGs reduces OPEX while its impact of CAPEX is not obvious. For example, if it leads to deferred investment costs if the grid, it reduces CAPEX. *Ruester et. al.* [7] opens the topic of rethinking the regulation of European electricity DSOs by shedding light on the missing aspects in the current regulations and providing insight on how regulation should be changed to incentivize DSOs to facilitate market entry of welfare-enhancing technologies in a timely manner and to manage DG-penetrated distribution systems, more efficiently. It concludes that the remuneration schemes for DSOs should be reconsidered to cope with the increasing network integration of DGs.

Increasing the number of electricity consumers becoming prosumers, and high penetration of distributed generators call for the revision regulatory mechanisms for network cost compensation and tariff structures. An analysis performed by *Küfeoğlu* in [8] on the impact of integrating electric vehicles (EVs) and Photovoltaics (PVs) on the distribution network under the current network tariffs for households in Great Britain indicates that increasing PV penetration increases the distribution tariffs for all customers, regardless of whether they have PV or not. While increasing penetration of EVs reduces the network tariffs for all customers.

Generally, distributed generators can lead to increase or decrease of the distribution network costs, and the tariff design acts as the main tool for allocating the costs to customers who own and operate these resource. However, currently DG owners do not pay network tariffs or are subject to the traditional pricing models for normal consumers, known as load-base pricing [9]. *Picciariello, et. al.* in [9] applies a pricing mechanism based on cost causality and the combination of net metering and pure volumetric tariffs, on the contest of increasing DG penetration and investigate the impact of this pricing scheme on the magnitude of cross-subsidies from consumers to prosumers. The degree of subsidy depends on the penetration of DGs, as well as the network characteristics, such that the rate of cross-subsidy is higher in low-density grids.

The integration of DGs into the distribution networks leads to additional costs for network operators related to connecting these technologies to the grid. From one side, the regulator should provide regulatory schemes which encourage utilities to invest on their networks, allowing for higher penetration of DGs, and from the other side, the potential interventions taken by DSOs should be recovered through a cost-reflective tariff mechanism. *Cambini* in [10] proposes a new multi-part tariff structure for prosumers, which is able to cover these additional costs under net metering approach, while minimizing the current deficiencies of net metering approach. The proposed tariff mechanism in [10] includes a fixed component reflecting the grid-connection costs and a variable component reflecting the operating costs of distribution networks.

Recently, distribution grid tariffs in many countries are being reformed to cope with the new characteristics of the networks, especially in terms of DG integration. While in Europe there has been legislative proposals to harmonize these reforms across the borders, many European countries have argued against this proposal and stated that distribution tariffs are local affairs. *Govaerts, et. al.* in [11] developed a long-run market equilibrium model which can capture the impact of wholesale market on the distribution grid tariffs. The focus of the study performed in [11] is on the spillover impacts of distribution grid tariffs in neighbouring interconnected countries through integrated wholesale electricity markets. The results indicate that unharmonized tariffs cause significant storage investment spillovers.

Vales, et. al. in [12] studies the regulatory barriers for integrating demand response programs into the distributed electricity networks from a European perspective. The remuneration mechanism of DSOs should be revised to incentivize the use of demand response programs when it is cost effective. According to [12], DSO regulations should be revised to incentivize operators to integrate demand response as a flexibility resource in their grid operation and planning. To this aim, the authors propose that there must be clear incentives for efficiency and innovation in long-term, without endangering regulatory stability. The remuneration is proposed to be based on output based regulation, incentivizing efficient OPEX and CAPEX, while accelerating depreciation and covering longer regulatory periods. From the network tariff perspective, they recommend to implement cost reflective tariff structure with capacity charge and dynamic tariff components, separation of non-network related component of the tariff, and flexibility to adapt tariffs to local conditions. Another study performed by *Annala, et. al.* in [13] indicate that demand response programs can reduce the environmental impacts of electricity utilization, however, there are still regulatory barriers, mainly on the customers' engagement in the programs. The analysis was performed based on a survey of Finnish electricity retailers and distribution system operators (DSOs). The participant suggested that the regulatory authorities should create incentives for DSOs to introduce power-based distribution tariffs for demand response providers.

An analysis preformed on the reflectivity and predictability of different distribution network tariffs for residential customers in [14] has indicated that peak load tariffs are the most reflective mechanisms in light of the energy transition, while energy use based tariffs can be most accurately predicted. According to the analysis in [14], the energy use has very close correlation with the distribution network losses, as losses are function of the energy transferred. Whereas, the peak loading of network which indicates the investments needed in the network, are less clearly linked to the energy consumption of households.

4 CURRENT REGULATORY ACTIONS IN EU

A synoptic view of the current regulatory actions implemented in the EU Member States and related to the network losses and their procurement by DSOs is reported in Table 1

Table 1 –Current regulatory policy actions in the EU-28. Source: JRC, 2020

Country	Policy Action
Austria	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses There is a maximum threshold for distribution network losses. The maximum loss level in this model should be assessed and reduced continuously. The maximum loss threshold approach lacks the differentiation between technical and non-technical losses
Belgium	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses A revenue cap mechanism is used for TOTEX (total expenditure) of the DSOs which includes cost of losses
Bulgaria	DSOs are incentivized to perform loss reductions as it is part of their costs. However, if other cost-reduction opportunities are provided to the DSO, loss reduction may be not a first driver DSOs are obliged to respect a given loss threshold, such that exceeding this threshold leads them to audit or non-recognition of the costs. This mechanism provides no incentive to save more energy by reducing losses to lower than the threshold
Croatia	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs
Cyprus	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs The responsibility of setting distribution tariffs is shared by the DSO, NRA, and government. The DSO calculated the allowed revenue, and the NRA approves the revenue allowance proposal of DSO
Czech Republic	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs DSOs are obliged to respect a given loss threshold, such that exceeding this threshold leads them to audit or non-recognition of the costs. This mechanism provides no incentive to save more energy by reducing losses to lower than the threshold
Denmark	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs Only about half (53%) of investments related to smart grid costs going forward are included in the regulated cost base. The other costs include the costs for system stability (installation of synchronous condenser and static var compensator), software, and meters

Country	Policy Action
	The regulatory has set revenue cap for DSOs that includes incentives to reduce power losses
Estonia	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs
Finland	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs
France	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs An incentive is applied on DSOs on the volume of losses and also the price of procuring energy to cover losses DSOs are obliged to respect a given loss threshold, such that exceeding this threshold leads them to audit or non-recognition of the costs. This mechanism provides no incentive to save more energy by reducing losses to lower than the threshold
Germany	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs The costs of losses are included in the revenue cap and is benchmarked regularly Distributed generators do not pay grid tariffs and the DSO tariffs are only charged to loads. Furthermore, according to the German law, newly constructed storages are incentivized by not paying network tariffs for 20 years German DSOs use 2-component network tariffs including a power based price and a power band price. Network costs are allocated to network users based on cost causation principle, taking into account the contribution of each user to the annual simultaneous peak load An efficiency bonus, based on a benchmarking process, may be issued to eligible DSOs. DSOs are eligible for this bonus only if they are determined to be fully efficient in the benchmarking process. This bonus is designed to enhance DSOs' innovation not only to be fully efficient, but also to try to exceed 100% relative efficiency, to achieve super-efficiency status DSOs are obliged to respect a given loss threshold, such that exceeding this threshold leads them to audit or non-recognition of the costs. This mechanism, by itself, provides no incentive to save more energy by reducing losses to lower than the threshold
Greece	The distributed energy sources do not pay for distribution grid tariffs but pay for the maintenance done by the TSO of the part of the grid which is solely used by them. Generators and importers are responsible for covering transmission losses while suppliers cover distribution losses
Hungary	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses
Ireland	Network losses are paid by the suppliers and not by the system operators, such that each supplier buys the energy needed to compensate losses caused by the consumption of its clients. Estimated losses are priced with wholesale market price to supply consumption
Italy	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs

Country	Policy Action
	In order to encourage more efficient technologies in transmission and distribution networks, the domestic electricity tariff has been proposed to be reformed. Based on the new tariffs, the tariff for energy transmission, meter management, and system charges, which accounts for nearly 40% of the customer's bill, would be identical for each consumption level. Therefore, the previous progressive structure of tariff based on incremental energy usage, have been abolished and domestic customers are paying about the actual cost of the services they receive. In the new tariff design, the standing charges in the total bill is increased for some customers (to around 25% of the total bill for domestic customers and 40% for non-domestic customers on average). The new tariff is expected to unlock the installation potential of energy-efficient electrical devices, e.g. heat pumps and electric vehicles, which have been hampered by the progressive tariff structures The government sets the annual national energy saving targets and the total obligation in terms of number of certificates for the obliged parties. The obliged and voluntary parties have to deal with final users to pursue energy savings
Latvia	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses
Lithuania	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses
Luxembourg	n.a.
Malta	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs
Netherlands	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs DSOs are incentivized to perform loss reductions as it is part of their costs. However, if other cost-reduction opportunities are provided to the DSO, loss reduction may be not a first driver There is a yardstick regulation in place with a target set ex-ante to a regulatory period based on historical results on the average performance of DSOs The grid costs of the DSOs in Netherlands mostly depend on grid capacity and not usage. This makes the use of capacity based tariffs fair in the Netherlands. Also capacity based tariffs significantly reduce the administrative costs for DSOs, compared to volume-based tariffs. As a result for customers, this tariff design is more beneficial for consumers with relatively high consumption compared to their capacity. Therefore, it reduces the incentive for energy efficiency, as grid tariffs do not depend on the usage
Poland	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs Losses on distribution network are set by a benchmarking approach Distributed generators do not pay grid tariffs. This is a benefit for DG owners while it may be disadvantage for other users especially when the costs that the DGs evoke to the network exceeds their benefits
Portugal	Network losses are paid by the suppliers and not system operators, such that each supplier buys the energy needed to compensate losses caused by the consumption of its clients. Estimated losses are prices with wholesale market price to supply consumption

Country	Policy Action
	Distributed energy sources do not pay grid tariffs, although smarter grids are needed to integrate more DGs and thus DGs should also be eligible to contribute in supporting the distribution system services The DSOs have specific incentives in forms of bonuses or penalties which is related to the DSO's performance and directly targets loss reduction. The incentive mechanism allows DSOs to be rewarded/penalized in case of achieving global distribution losses below/above the threshold set by the National Regulatory Authority, on a yearly basis In Portugal, time of use (ToU) tariffs have been implemented for a long time by a significant percentage of consumers, representing 80% of total demand.residential consumers can choose among tariffs with one up to three time periods. ToU tariffs provide incentives for consumers to do load shifting In Portugal, the regulatory framework for implementing dynamic ToU tariffs for grid access has been created by the regulators with the aim of enhancing the active participation of users [20]. Dynamic tariffs enable consumers to participate in mechanisms that minimize the grid costs, provide alternative mechanisms for grid operators to minimize cost and postpone new investments, and enhances operational security by minimizing the impact of production variation from renewables
Romania	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. There is a dedicated tariff for network losses
Slovakia	The DSOs have specific incentives in forms of bonuses or penalties, which is related to the DSO's performance and directly targets loss reduction
Slovenia	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs The costs of losses are included in the revenue cap and is benchmarked regularly
Spain	Network losses are paid by the suppliers and not system operators, such that each supplier buys the energy needed to compensate losses caused by the consumption of its clients. Estimated losses are priced with wholesale market price to supply consumption Loss reduction of DSOs is addressed through a benchmarking approach among all the Spanish DSOs on their performance
Sweden	System operators are responsible to procure the power for covering losses of the network they operate. Average costs of losses are approved by the National Regulatory Authority (NRA) and used in the calculation of tariffs. The costs of losses are included in network tariffs The DSOs have specific incentives in forms of bonuses or penalties which is related to the DSO's performance and directly targets loss reduction In Sweden, distribution tariffs are not set by national regulators, but are set by the DSOs, under certain legal requirements The energy efficiency directive has been implemented in Sweden such that the tariff must incentivize efficient use of the grid and efficient energy production and usage. The Swedish national regulator supervises the tariffs' structure to ensure these requirements The tariffs vary greatly among the DSOs in Sweden, with highest tariffs for small DSOs with rural distribution There is the regulatory framework of income-cap under which each DSO decides which tariffs to apply, in terms of proportion of fixed and variable costs, time of use tariffs, capacity based tariffs, … Customers receive 2 bills, one from the DSO and one form the retailer

Country	Policy Action
	DSOs are responsible to keep their total revenue within the limit during the regulatory period (4years). Under this approach, the tariffs are likely to stay stable for a longer period without transferring their management from DSOs to regulators Domestic customers' tariffs are usually composed by a fixed (based on the size of user) and a volume fee (per kWh), while larger customers' tariffs include fixed fee, a capacity fee based on subscribed capacity, and a volume fee. However, with the increasing integration of smart meters, it is possible to implement dynamic or hybrid time of use tariffs and capacity based tariffs also for small residential customers
United Kingdom	Network losses are paid by the suppliers and not system operators, such that each supplier buys the energy needed to compensate losses caused by the consumption of its clients. Estimated losses are priced with wholesale market price to supply consumption Distributed energy sources pay network tariffs under 2 methodologies: 22 kV or above Extra-High-Voltage Distribution Charging Methodology (EDCM), and Below 22 kV Common Distribution Charging Methodology (CDCM). Under EDCM methodology, a specific tariff is produced for each customer. Under CDCM, different tariff categories in each DSO area are set and each customer belong to a tariff category The DSOs have specific incentives, in forms of bonuses or penalties, which is related to the DSO's performance and directly targets loss reduction In UK, the distribution network tariffs are based on long-run quasi-incremental cost approach, based on the annualized cost of a scaled hypothetical network model which characteristics match the one of the actual network. This methodology is used for all consumers connected to below 22 kV network. These tariffs do not involve any locational signal, but are mainly reflecting the characteristic of the network and consumers in each DSO. The CDCM approach applied on below 22 kV consumers assumes that only consumptions at system peak period impose costs on the DSO and the cost per unit of demand in peak time is determined through a distribution reinforcement model. The cost is calculated based on the estimated costs for DSOs to install, maintain, and operate the assets needed to serve a hypothetical network to supply 500 MW of demand. Then, the total cost is allocated to different customer classes (totally 27 user groups) based on their voltage level and profile class

Table 2: Synoptic view of regulatory (tariffs + incentives) across EU. Source: JRC, 2020

Country	Procurement		Tariffs				Main Incentives					
	DSO	Supplier	Dedicated tariff for losses	Cost of losses included in network tariff	No tariffs for losses	Recovered by other charges	Maximum losses threshold	Cost of losses / incentives as part of the revenue cap	Incentives on volume of losses	Incentives on prices	Efficiency bonus for DSOs	Yardstick competition mechanism
Austria	X		X				X					
Belgium	X		X					X				
Bulgaria	X			X			X					
Croatia	X			X								
Cyprus	X			X								
Czech Republic	X			X			X					
Denmark	X			X				X				
Estonia	X			X								
Finland	X			X								
France	X			X			X		X	X		
Germany	X			X			X	X			X	
Greece		X			X							
Hungary	X		X									
Ireland		X			X							
Italy	X			X								
Latvia	X		X									
Lithuania	X		X									
Luxembourg												
Malta	X			X								
Netherlands	X			X								X
Poland	X			X								
Portugal		X			X		X				X	
Romania	X		X									
Slovakia	X					X					X	
Slovenia	X			X				X				
Spain		X			X							
Sweden	X			X					X		X	
United Kingdom		X			X						X	

5 PLAYERS' PERSPECTIVES

This section gives an overview of the stakeholders' consultation done on the subject regarding the potential measures to be implemented towards the efficiency increase of the electricity grids.

The players contributions were gathered by interviewing the stakeholders' representatives via a structured questionnaire and then transcript into the following texts:

5.1 Knud Pedersen, Chair of Eurelectric Distribution & Market Facilitation Committee

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks? Which is the role played by transmission and distribution respectively?

The future investments needed for the electricity network (especially in a perspective of a wide electrification) will be more related to distribution part than to the transmission one. It has to be highlighted that, talking about investment in distribution grid, the national differences among EU countries may be significantly relevant. However, in general, the investment cost is the largest part of the total cost (accounting for about two third), and there are huge potential for enhancing the CAPEX efficiency in the distribution grid, by improving planning and increasing the capacity utilization being more interactive with customers flexibility.

Considering the technical interventions for increasing the energy efficiency of the network, reducing losses, relevant aspect are the introduction of remotely read meters and the digitalization of the system (with more sensors and the possibility of obtaining a higher amount of data), allowing to have a more precise picture of the grid, and – in particular – to better quantify losses, thus being able to effectively act in order to reduce them and obtaining a better management of the grid itself. Nevertheless, it has to be underlined that, from the economic point of view, losses have a lower impact on the total cost of the network with respect to the investment cost, which remains the key component on which acting for enhancing the economic efficiency.

Losses account for about 4% of the total amount of electricity delivered, while from the economic perspective they could weight for about 15% of the overall cost for operating the distribution system.

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

The ways in which the regulatory framework is implemented in the individual EU Member States vary significantly: the specific regulations may incentivize efficiency improvements in different manners, and in some cases there may not be significant incentives for effectively enhancing energy efficiency.

Furthermore, there is not link between the general energy efficiency instruments at EU level and the economic regulatory framework for infrastructure companies: in the modernization of the regulatory framework, some kinds of incentives for companies in order to pursue energy efficiency should be set, but – in different cases – this did not happened.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

The only natural way is that DSOs purchase the amount of energy needed to cover the losses. Of course, in many countries DSOs who have the obligation to cover the losses have to buy the amount of electricity needed in the competitive market, so is the supplier that deliver the electricity to them. However, it has to be underlined that in both cases of technical and non-technical losses is up to the DSOs (who have the proper instruments) to find the right way to limit them, as it will be difficult for other subjects to act in a proper way.

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

First of all, standardization for specific technology equipment should be relevant in order to introduce some kind of mandatory elements on the system and intrinsically increase its efficiency. However, the best option for progressing in enhancing energy efficiency is to set incentives to people and to companies for implementing efficiency improvements.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:

Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)

Allowed rate of losses to include in tariffs capped to a maximum percentage value

Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value

According to your opinion, which is the best one and why?

The first method is preferable and recommendable. It is important to start from the current situation and put incentives inside the revenue cap (with a regulation that gradually increase the ambitions), in order to incentivize DSOs to make transparent the progresses on energy efficiency enhancement and on lowering losses.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

The losses need to be reflected into the variable part of the tariffs, as they are related to the amount of electricity transported and distributed.

- The current regulation related to electricity and gas could allow an effective cross-vector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

There are many possibilities. The starting point is to take into consideration the infrastructures that are already available in the country (for instance, in Denmark there are both modern and efficient gas and electricity grids).

Of course, a major part of decarbonisation process is related to the electrification coupled with the power generation from renewables. However, gas could play a significant role in this process. For example, referring to heating sector in Denmark, in areas where there are a lot of natural gas individual boilers for heating purpose, it is possible to quite easily reduce the demand for fossil gas by introducing heat pump. However, another relevant option is to combine heat pumps with gas boilers, because during very cold days heat pumps are not very efficient and in areas where there is not a lot of wind electricity price might be high (while the gas price could remain stable). Consequently, it could be possible to lower the total amount of fossil fuels with a smart interplay and a system partly based on gas and partly on electricity.

Moreover, looking at power-to-hydrogen option it could be possible use (at least partially) the already existing gas infrastructure or it could be possible to progressively to introduce more “green” gas (like biogas) in the grid. These are options for exploiting in the best way the existing infrastructures also in this framework of energy transition.

In general, there are several specific opportunities, with technologies already available, and there could be economic and financial benefits for households, society and companies.

- From a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

There would not enough economic bases for substitution of older transformers with new ones before they end of lifetime. The improvements from the economic point of view are so little that they cannot justify this.

Most of efficiency improvement that they have detected are related to the way in which they operate they assets.

Of course, when investments in new transformers and lines are needed, it is necessary to ensure that there is a standardization of these technologies, in order to have the best efficiency already potentially integrated in the technology itself.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

It should be based on a structure combining the standardization of the specific technologies, a guideline for the economic regulation of the revenues flow and finally a guideline related to how to optimize (from a financial point of view) reinvestments related to the perspective of efficiency improvements (how they can be monetized and quantified in the right way).

5.2 Roberto Zangrandi, Secretary General of EDSO (European Distribution System Operators)

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks? Which is the role played by transmission and distribution respectively?

First of all, the question in divided into two parts: increase in efficiency in distribution and increase in efficiency in transmission.

Referring to distribution, it is needed an enhancement of the concept of sandboxes, both from the regulatory and design perspective. In this sense, ACER plays a major role, and it should stay on the side of distributors, encouraging and following the efforts in deploying new technologies in smart grids and the smart use of the grid. It is not easy, but an acceleration in demonstration and the testing of cutting edge technologies in the management of the grid is needed.

Incorporating RES at local level is a priority, but it is necessary to introduce, beside this, all the possible experimentations and proposals related to the increase of local resilience and of resilience techniques. When considering that the DSOs are the main enablers for active consumers, for the use of platforms, for active asset management at local level, the role of the resilience techniques (that must be at the basis of every experimentation) cannot be forgotten.

Enhance sandboxes means also not to anticipate regulation for future technologies but adapting the existing and upcoming regulation to what technology is about to offer. An example is represented by the proliferation of the charging units for electro mobility. In the main European countries there is the possibility to have individual houses equipped with a charging unit for electro mobility. When preparing an individual house by delivering a charging facility for personal use, the possibility to share this charging facility by authorizing citizens to provide a charging service outside their houses should be foreseen. Currently, there are not regulations allowing citizens to share their charging points: this aspect should be discussed with ACER and CEER, because private citizens could play a significant role not in managing the grid, of course, but in enabling the grid – with the support of DSOs – to render a public and widespread reliable service.

Regarding TSOs, they seem to play so far their game in order to acquire a kind of shared sovereignty on the use of consumption data coming from the consumers. The issue of the ownership of data and the possibility to share the use of data is a vexed question between DSOs and TSOs. Many regulatory drivers in Europe show that as far as the data management is concerned, the National Regulatory Authorities (NRAs) are inclined to allow the TSOs an advantage in the use of data. On the other side, the TSOs consider the ownership of data for technological purposes and not for commercial purposes their exclusive pertinence.

The concept of data evolves and the evolution of this concept is something that is not often considered by the analysts that are active in shaping the regulation. The nature itself of data changes with the evolution of technologies: it can be possible to divide private data, commercial data and technological (measurement of consumption, loads, average voltage, etc.; operative data that can be useful in the interchange between TSOs and DSOs) or operational data.

This is the main item for an effective cooperation. DSOs must reopen the folder of data discussion with TSOs and retailers. In synthesis, the relation between TSOs and DSOs is deeply influenced by how data are managed, considered and shared.

The evolution of data is the main worry. In fact, there are data that will be provided beyond the meter (and that are more sophisticated and accurate in term of granularity than those provided by smart meters) by the connection of intelligent appliances to the domestic network: it is the Internet of Things (IoT), which is going to major play a role in the individual households.

The market will generate a set of alternative data deriver by the connected appliances that are out of any possible regulation and that are in a condition to change structurally the market use of those data.

Referring to the technological impact on efficiency, there is, in the framework of the Clean Energy Package delivered by the EU Parliament, a lot of discussion on the notion of storage.

DSOs have always seen storage as essential tool for the management of the load and the balancing of locally generated imbalances in frequency. This is going to play a strong role in the future due to the relevance of RES, but it is going to be strongly regulated by the NRAs and opens spaces for the market. No commercial storage should be owned or operated by the DSOs. DSOs have to fight a lot to convince the legislative process to accept a moratorium on this, in order to grant the DSOs themselves the use of storage until market shows up.

Second, this is only one example: we do not want to see the same regulation interference as far as the cutting edge technologies (rewiring, superconductors, high technology transformers, etc.) are going to be deployed.

The parts that are essential to shape the grid of the future have also such a big market impact and a big role in designing the investments that DSOs are going to undertake in the next years that must be strongly considered.

The Clean Energy Package foresees the necessity of 260 billion € per year of investments. The DSOs as a whole are around 25 billion (10%) per year of this investment. If it can be considered that the acceleration of the technologies can be supported and that there will be money enough to be invested in the hyper-modernization, there could be the possibility to test and embrace cutting edge technologies and to make strong investments in order to have hyper-performant grids in the future. It is important, however, to have, from one side, an evolutionary path for supporting the modernization of the grid but, from the other side, this should be done without destroying the investments already made in the grid. The challenge, speaking about the hyper-performant elements of the grid of the future, is not to generate a high amount of stranded costs, which will be on the shoulders of DSOs and probably of the consumers.

A possible risk is instead a widespread not coordinated use of cutting edge technologies, which could lead to have in Europe the coexistence of a hyper-performant grid on one side and a very poor grid on the other side. It is necessary to avoid a huge grid divide because it would cause huge costs for the system (DSOs and TSOs). The risk is related also by the fact that these cutting edge technologies require a system of monitoring sensors, and this will probably still certify the difference between the services rented to industries and consumers in different areas of different countries.

To summarize, the sandboxing and the experimentation also for cutting edge technologies, with a severe impact assessment of economic cost for industry and social cost of the society, are absolutely important.

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

It is ready and adequate at 75%. Regulators are not enemies but partners, and they are doing efforts to coordinate among themselves and with the regulatory authorities. They must coordinate with the evolution of the rest of Europe that is still not belonging to the EU but that is going to adopt the same regulatory framework in order to harmonize in an efficient way the interconnections at TSO level and, in the future at DSO level. Going back to the sandboxing, it is essential to cover the gap. A wide coordination of the regulatory efforts at EU level is necessary, also for DSOs that have to agree on the guidelines related to the evolution of regulations.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

It depends on the quality and accuracy of metering of the energy flows along the whole grid.

There is a shared responsibility between TSOs and DSOs but the most of the accuracy comes from DSOs, even if there are countries where, due to the lack of smart meters, probably the suppliers and retailers ensure more accurate data. It has to be underlined, however, that grid losses have been reduced a lot during last years.

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

In the future, the orientation is to provide mandatory provisions. For the transition, most probably to incentivize the support is the better way. The transformers do not have a long life cycle and the worry of generated stranded costs is very strong in the financial planning of operators. It the mid/long term the more effective option will be the mandatory regulation, in order to manage in an efficient way the electric system at EU level, but in the next 10-15 years an incentivized basis for regulation must be adopted.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:

Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)

Allowed rate of losses to include in tariffs capped to a maximum percentage value

Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value

According to your opinion, which is the best one and why?

It is a very specific question. In fact, also the profile of losses changes between DSOs and within a DSO network. For instance, thinking about Enedis, in France, it can be observed that they adopt at least 7-8 different local profiles for the evolution and planning of their grid and produce 7-8 approaches to regulatory solutions in order to solve or monitor the losses that they generate.

Different DSOs can have different attitude towards the three mechanisms, due to the fact that, in terms of losses, there are different behaviours of the networks among different countries, so it is reasonable to have different regulations in different countries.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

It is very specific. The management of losses is one of the parameter of the performance of DSOs, it is an economic performance indicator and it is a market performance indicator. A system rewarding the strict management of the losses and the compensation of the reduction of losses on a percentage basis could be a fair solution.

- The current regulation related to electricity and gas could allow an effective cross-vector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

The sector coupling is a notion that is far beyond gas and it is a rationalization and an integration of systems related to the energy and data management that will require relevant investments. This question should be extremely split, because it refers to an integration among different networks based on a concessions system that is critical (from an organizational perspective) for the consumers. The fragmentation and structure of the different concessions between electricity and gas, the difficulty of combining the duration periods of concessions and the localization of these concessions lead a high difficulty in defining a coordinated approach for the development and modernization of these two distribution networks.

There could be two approaches. One is the commercial one (mainly adopted by the small distributions), which starts from the status of the grids, implements modernization actions where they are requested, and produces value from the combination of the two sectors (electricity and gas) under the administrative point of view, reducing the costs for the individual customers. The second approach, which should be the correct one, stars instead from the comparison of the technological status of the two grid, checking if sufficient investments have been performed in order to have smart meters in both of the networks, thus ensuring accurate measurements, verifying if the citizens have been properly encouraged (independently from the retailers) to use condensing boilers (that could ensure an effective sector coupling, profitable also for final customers). Furthermore, it requires to verify if those measures have to be undertaken due to an obligation or to incentives provided by the regulation, and which is the role played by the competitors in the regulatory framework.

The Power-to-Gas, for instance, has several implications, ranging from the role of TSOs in the management of the High Voltage transmission (requested by the PtG process), to the introduction in the strategic choice (w.r.t. the more general framework of the need for electrification of final uses) of a variable that can modify the normal supply of electricity for its common uses (lighting and electrical mobility). A key question is: what could happen if the subjects that produce and transport electricity will see in the transformation of electricity into another energy commodity (namely, gas) a higher profit w.r.t. to the one generated by the use of electricity for the common purposes? Moreover, in the next future there will be investments dedicated to the PtG? Who will make these investments? The development of PtG will use the current electricity network? Finally, who will define the priorities? In the choice of priorities, the situation will be in fact very complex, involving not only the market dimension, but also the economic and the political ones.

- From a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

The combination of electronic measurements and of a dynamic management of the storage.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

The solution is: a common reference framework, guidelines instead of strict regulatory obligations, a very basic strict regulation for tariffing standards and the possibility to experiment and open up cross border distribution at lover tension level (cross border interconnections at distribution and not only transmission level), and encouragements for DSOs to support local communities in interacting among themselves.

This is only possible with digitalization, interactive platforms, smart metering, smart management of the grid, etc., but it is necessary to give the right for neighbouring communities to interact with the distribution system even if the distributors are different.

The goal is an integration of the neighbouring resources, which could allow to active citizens to participate and to optimize the great capillarity of the electricity network.

5.3 Charles Esser, Secretary General of CEER (Council of European Energy Regulators)

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks? Which is the role played by transmission and distribution respectively?

It depends on the kind of scheme for incentives for TSOs and DSOs and on the tariffs structure. With respect to the technical aspects, the EU Directive setting technical criteria for the new transformers can be mentioned.

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

There are different national views on this issue. It has been effective in the northern European countries.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

Considering as an example the Finnish case, in Finland the responsible are the DSOs, which have to tender for losses. There is a market mechanism to acquire the electricity needed for compensating losses: in this way it is possible to minimize the related cost, which is then charged back to final customers in the tariffs.

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

It is possible to have at the same time some mandatory components and some incentives schemes. A combination of minimum technical standards and incentives is the best option.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:

Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)

- o Allowed rate of losses to include in tariffs capped to a maximum percentage value
- o Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value
- o According to your opinion, which is the best one and why?

The first one is the best one.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

It is a difficult to give a unique answer. In Finland, for example, losses do not play a relevant role in tariffs. Generally speaking, it should be avoided to have too much pressure on DSOs regarding this aspect, putting too much attention on losses in the tariff design.

- The current regulation related to electricity and gas could allow an effective cross-vector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

It is difficult to presently understand the possible evolution in terms of cross vector-integration, which could involve not only electricity and gas DSOs, but also those related to district heating and water distribution.

- From a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

There are several differences among countries (in different areas there could be different return rates of the investments), so it is difficult to generalize.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

A common guideline should be set.

5.4 The Council of European Energy Regulators (CEER)

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks? Which is the role played by transmission and distribution respectively?

Sweden - **Ei**

- Transmission? Better coordination with DSOs, customers and TSOs in neighbouring countries. Better long planning process to meet future challenges in a cost-efficient way. Evaluating new kind of solutions such as DLR. The role compared to DSOs is to have the overall coordination, both national and with other countries. They also have the role to develop methods/policies (often together with ENTSO-E).
- Distribution? Varies a lot between DSOs (Sweden has >170 DSOs with very different sizes etc.) Some DSOs could do much more, while other do a relatively good job today. Some are at a regional level close to the TSO (called sub-transmission in many countries), while others are very local with only LV and MV. They also have to be better on long term planning in a cost-efficient way, both for own investment planning and to give information for DSOs and the TSO at higher voltage level (so they can do the correct long-term planning). They should also consider working with developing tariff that better incentivize a more even load and that reflect actual costs. They should also evaluate new solutions when relevant. Some small DSOs has also potential working of reduce non-technical losses even if Sweden in overall has relatively good metering.

The Netherlands – ACM

We currently do not have an overview of concrete actions planned or executed by TSO and DSOs with regard the increase of energy efficiency of their networks as this is only implicitly incentivized through the tariff regulation on the reduction of total cost.

Slovenia – AGEN

AGEN welcomes activities that are targeted into promoting the development of the network concept with minimal losses (e.g. underground cabling, incorporation of new technologies, introducing low-loss transformers, development and implementation of advanced metering systems, replacement of energy equipment, implementation of network configuration optimizations etc.).

Belgium

Federal (CREG- transmission):
The transmission tariff methodology includes incentives toward efficiency, such as revenue cap on Opex, incentive on innovation activities, CBA on large infrastructure projects and an incentive to maximize the availability of existing interconnection capacities. The transmission network should enable the energy transition in the most efficient manner, offering reliable transportation capacities at minimum costs.

Flanders (VREG-distribution):
A good regulatory framework should incentivize the system operators to make deliberate investment decisions.

Brussels (BRUGEL-distribution)

The Brussels DSO is concerned to minimize its losses on the network but does not pursue a specific investment policy aimed solely at this objective.

The DSO opts for the application of an opportunistic policy aimed, on the occasion of investments decided for other reasons, at seeking the most energy-efficient technical solutions.

Among the planned investments are the following:

- harmonization of the medium-voltage network towards an increase in the voltage of the 5/6.6 kV networks to 11kV;
- opportunistic development of the low voltage 230V network towards the 400V network;
- the installation of high-performance MV/LV transformers;
- Exploitation of LEDs and the use of dimming (for public lighting activities).

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

Sweden - Ei

- Yes, but what is expected for transmission and distribution? Both the TSO and the DSOs have economic incentives to reduce network losses, that can increase or decrease the regulated revenue cap. The TSOs and regional DSOs (sub-transmission) are benchmarked with their own historical levels to improve, while local DSOs are benchmarked with each other (adjust for that that they have different objective conditions: customer density and voltage levels). All DSOs has also an economic incentive to have a more even load profile using the load factor as an indicator (they are compared with their own history).

The Netherlands - ACM

In the Netherlands the TSO and DSOs are responsible for the procurement of energy losses. Also they are financially incentivised to reduce the total costs of ownership and operation (including energy losses) through our tariff regulation. Through this the network operators are incentivized to procure energy in an efficient manner and to take into account energy losses in the replacement of grid assets, as, for example, the energy losses increase with the lifetime of a transformer. For the new regulatory period, ACM considers increasing the financial incentives further.

Slovenia - AGEN

In the current regulatory framework (years 2019-2021), AGEN is implementing certain actions to achieve energy efficiency targets (such as incentives to reduce network losses), but there are (yet) no precise targets set to achieve costs efficiency and energy efficiency of electricity networks on larger scale.

Belgium

Federal (CREG):

We believe so. However, the new transmission tariff methodology is applied only since January 2020. A review of the provisions aiming at this goal, notably the above mentioned incentives, will be carried on from 2022.

Flanders (VREG)

No, once there are potential measures identified, there is no further obligation or stimulus for improvement**.**

Brussels (BRUGEL)

The Brussels power network is an urban network and the power losses are estimated at approximately 3% (technical and non-technical losses). However, the current regulatory framework is considered not sufficient enough, because it is not binding.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

Sweden - Ei

The network operators would be responsible.

The Netherlands - ACM

The procurement of energy losses should be under the responsibility of the network operators.

Slovenia - AGEN

AGEN believes that this task should be performed by the electricity network operators.

Belgium

Federal (CREG):

We believe TSOs should be responsible for the procurement of energy losses as it allows a regulatory supervision and incentives toward efficiency. TSO procurement would improve transparency and non-discriminatory socialization of the costs. The transmission tariff methodology foresees an incentive for the TSO to efficiently purchase the energy to cover the transmission losses.

Currently, in Belgium, in application of the legislation, BRPs are responsible for the procurement of the energy to cover high voltage transmission losses. However, the legislation has recently (2019) been modified allowing this responsibility to be borne by the TSO, under proposal from the TSO and approval from the NRA (CREG). As to this date, such proposal has not yet been received by the CREG.

Flanders (VREG)

Network operators, so that they have an incentive for improvement of their assets.

Brussels (BRUGEL)

The procurement of electricity for covering the losses is done by the DSO via public tenders challenging the various offers from the suppliers. This system puts the responsibility on the DSO but the regulatory authority has the right to view the applied prices and can eventually refuse them if these are unreasonable

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

Sweden - Ei

  - Ei is of the opinion that incentives are a better way to move forward.

The Netherlands - ACM

ACM thinks that it is best to incentivise network efficiency on a total cost level, including the procurement of energy losses.

Slovenia - AGEN

In order to increase the energy efficiency of electricity networks, binding targets should be set at least at the transmission networks level, or on the EU single market respectively. However, the mechanism for achieving energy efficiency targets should be implemented through incentives for electricity network operators.
AGEN believes that lower comparability between distribution systems may make it less efficient to achieve uniform energy efficiency targets at EU level.

Belgium

Federal (CREG):
Incentives. NRA should define targets (efficiency gains) to be achieved by the TSO. Part of the efficiency gains should then be granted to the TSO as a reward. The regulator (NRA of public authorities) are not in a position to efficiently define mandatory target. The TSO should be incentivized to pursue the optimal volume of network losses striking an optimal balance between cost of losses and costs of investments to reduce losses.

Flanders (VREG)
Agree (potentially linked to incentive regulation).

Brussels (BRUGEL)
The actions could target investments (by recommending specific prescriptions and norms) and on a regulatory level via tariffs, but the driver for the DSO will probably remain the cost reduction.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:
    - Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)
    - Allowed rate of losses to include in tariffs capped to a maximum percentage value
    - Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value

According to your opinion, which is the best one and why?

Sweden - Ei

- The third mechanism (reward/penalty) is used in the Swedish regulation. It may result in an increase or decrease (adjustment) of the annual regulatory return on the regulated asset base (RAB).

The Netherlands - ACM

Incentive-based regulatory models, as they incentivise grid operators to minimise the total costs. The grid operator is best placed to determine for example how/where energy losses in its grid can be reduced best and what the corresponding costs are (e.g. replacing a transformer).

Slovenia - AGEN

AGEN believes the best approach of the above is the 3rd option due to introduced penalty-reward scheme which in order to encourage network operators to achieve lower electricity network losses.

Belgium

Federal (CREG):

We believe, at transmission level, that volume of losses are barely in the hands of the TSO. Therefore, negligible it would be ineffective and unfair, hence inefficient, to impose ex-ante targets on volumes of losses. However, TSOs responsible for the procurement of energy to cover losses have an influence, although limited, on the price of this energy. Therefore, setting efficiency target in prices and granting part of the gains finally achieved to the TSO would our preferred option, as in the first mechanism above. This incentive could target the costs of losses (volume * price) in order to act also on volume, in the limits of the TSO's impact.

Flanders (VREG)
Energy losses are already under the responsibility of the distribution network operators and thereby already included in the revenue cap. A maximum allowed rate of losses will not always lead to the most efficient investment. A reward or penalty mechanism seems the best way to stimulate network operators to implement energy efficiency measures.

Brussels (BRUGEL)

This is a complex question and the answer depends on the regulatory context and the level of network losses of the DSO's.

The cost of losses depends on the percentage of the losses (volume) and the cost of procurement for covering them. Taking into consideration only the percentage of the losses such as suggested in the 2nd point does not seem optimal. The first and the third point can coexist: treat losses like other costs and give incentives (bonus/malus) on Loss-related KPI's.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

Sweden – Ei

The reward/penalty model.

The Netherlands – ACM

ACM thinks that on itself the way the allowed revenues are determined are more important than the tariff design. That being said, energy losses are generally higher when the actual capacity used on the grid is higher, as losses rise exponentially. As such, a network tariff structure that incentivises grid users to avoid capacity peaks can contribute in reducing energy losses.

Slovenia – AGEN

AGEN believes that a volumetric tariff component (EUR / kWh) for the payment of the electricity network charge would be appropriate to represent clear price signal to the electricity network users to reduce network losses; this kind of tariff component should include also a time signal, when network losses are higher.

Belgium

Federal (CREG):
A tariff design that leads to a reduction of network losses can only be efficient if the party that has to pay the tariff can have a noticeable impact on the grid losses. Most grid users do not have such an impact.
That is why we think that a tariff design should also foresee incentives for the network operator to operate and develop the network at the most economical way taking losses into account. The tariff design should also foresee incentives for the network operator to compensate the non-avoidable losses at the lowest costs for the grid users.

Flanders (VREG)
Tariff design is not only focused on reducing network losses but total network cost in the first place.

Brussels (BRUGEL)

This is not confirmed, but defining a tariff structure that provides an incentive for users not to use the network (or use it less) at times where it is overloaded could help to reduce losses as they are exponential at the level of the cables ($P = R*I^2$). The use of multiple timeframes for distribution tariffs could be considered.

- The current regulation related to electricity and gas could allow an effective cross-vector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

Sweden - Ei

- No, in Sweden the gas-sector has a very low part of the energy market (2-3%) and are limited to a minor geographical area.

The Netherlands - ACM

ACM has not yet determined what if current regulation would or would not allow an effective cross-sector integration but is willingly to exchange thought on this subject.

Slovenia - AGEN

Due to the lack of objectives, the current regulatory framework does not (yet) cover effective cross-sectoral integration in terms of increasing energy flexibility. AGEN believes that in this direction, basic objectives and strategies in the EU area should be defined well.

Belgium

Flanders (VREG)
Question unclear

Brussels *(BRUGEL)*

This is a topic on which no assessment or decision has been made yet because of the uncertainty of the future of the gas network.

- *From* a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

Sweden - Ei

- Procurement of flexibility, e.g. energy storage and more local production.

The Netherlands - ACM

Technical losses can generally be distinguished in (1) losses over the grid, depending mostly on actual capacity used on the grid and (2) losses over components, depending mostly on age and quality of those components. Considering the last, an advisable action for grid operators is to take into account what the energy losses of a component are in the decision when to replace it. Another point of attention is the voltage level in relation to capacity needed as higher voltage generally comes with lower losses per kWh transported.

Slovenia - AGEN

AGEN believes that a proper combination of actions on network operators' side (e.g. investment to reduce network losses, various operational actions, etc.) and on network users' side (e.g. real responsiveness to the tariff system, energy efficient, etc.) could gradually achieve increased energy efficiency of electricity networks.

Belgium

Federal (CREG):
A more efficient use of existing network infrastructure does generally lead to an increase of losses. Closely monitoring the temperature of conductors, for instance, will permit that the lines can be operated at a higher average load with an increase of useful capacity but also more losses as a consequence. Such an increase in capacity is usually economically justified despite the increase of losses. However, when designing new infrastructure, the network operator should be obliged to take also the losses into account. New infrastructure should be optimized not only for needed capacity but also by taking the economic value of the losses over the lifetime of the new infrastructure into account.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

Sweden – Ei

- Transmission?
- Distribution?

Both DSOs and TSOs: Set goals and recommend economic incentive schemes, but it should be up to the Member States to set details that fit specific conditions of each Member State.

The Netherlands – ACM

ACM thinks that it is best to incentivise network efficiency on a total cost level, including the procurement of energy losses although specific requirements on loss levels for components used in the EU could also be a method for general loss reduction.

Slovenia – AGEN

Good practice
An example of good practice is to effectively determine network losses with the establishment of the identification of real (actual) network losses; this is actually reflected with the increasing of the share of advanced measuring devices installed in the electricity networks.
Recommendation
To find common goals at EU level (primarily at the level of transmission networks in order to create equivalent conditions for the proper functioning of EU internal market) and to find incentive mechanisms to increase energy efficiency of electricity networks. It is also necessary to introduce the effective control.

At national level, incentive mechanisms should be put in place to identify energy efficiency targets for electricity networks and consequently which should lead to the creation of common targets at EU level.

Belgium

Federal (CREG):
The obligation to take the economic value of the losses over the lifetime of into account when designing new infrastructure.

5.5 Jochen Kreusel, Vice President T&D Europe; Laure Dulière, Policy adviser T&D Europe

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks? Which is the role played by transmission and distribution respectively?

It is necessary to distinguish between passive and active contributions. Active contributions are those related to the use of efficient components, especially transformers (for them there are already measures available, related to new installations). Transformers are relevant because they provide the major contribution to losses and, consequently, associated to them there is the highest possible efficiency gain. Secondly, constructing new lines or reconstructing lines, the load situation changes and the operation of the system has to be performed according to an optimization of the power flow, able to minimize losses. Therefore, there are two kind of interventions leading to impacts on losses: structural interventions, using efficient components (e.g. installing new transforms) and operational interventions (e.g. optimal dispatch). The first is more easy to implement and to measure, the second (strongly depending on loads and grid structure) is instead more difficult to quantify.

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

It is important to have economic mechanisms setting strong incentives, higher with respect to the current ones, that could be effective for new installations, choosing the more efficient components, but not in pushing the replacement of old inefficient components, like transformers (whose average age in Europe is equal to several decades). The advantage of Energy Efficiency Directive is that it makes visible that energy efficiency contributes to save energy, but to materialize these savings the EED has to be put in parallel with the market design.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

The network operator should be in charge of this, as it is the subject that can invest and take action to reduce network losses, but it should clearly see the costs and the benefits of doing this, and stronger incentives – as previously mentioned – are required.

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

A special attention to efficiency has to be payed in regulation, which could be both a mandatory regulation setting minimum standards and a special treatment of cost of losses, eventually also allowing a certain amount of cost of losses being reinvested. An example of "stick and carrot" measures is represented by Spain, where the better performing operators get a bonus coming from the penalties applied to the less performing DSOs; this is a good way for promoting best practices for operators.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:
    - Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)
    - Allowed rate of losses to include in tariffs capped to a maximum percentage value
    - Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value
- According to your opinion, which is the best one and why?

The first one is weak and in the best case gives incentives to select more efficient components when they have to be replaced. Therefore, it can be considered when investments have to be done, but it results very weak. The second is a little bit stronger but setting a maximum does not provide incentives to take actions for doing more. The third one is the stronger one, giving an active signal to network operators and pushing them to enhance efficiency.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

A tariff is a price payed by the user of the grid. Tariffs may be incentivised, but this is an efficiency outside the network, is not acting on the efficiency within the network. Of course, a volumetric tariff encourages to consume less, but this means reducing electricity consumption, without a direct effect on the network losses. Therefore, tariffs cannot impact on the efficiency of the grid itself, but are a price signal to the outside front.

- The current regulation related to electricity and gas could allow an effective cross-vector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

One aspect is that there is no aim of a consistent price structure between gas and electricity. In fact, for instance, over past years, in several EU Member States there were increases in electricity price due to energy transition and the increase of renewables in the power generation, which means distorting pricing disregard choosing between electricity and gas. This is not a supporting situation for electricity penetration. If we assume that the role of electricity has to increase in order to support the energy transition, putting all the cost burden on the electricity side will be not appealing for users. It has however to be underlined that, according to the European Green Deal, the carbon impact of fuels is becoming more important, favouring electricity from RES.

- From a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

From the technical point of view, every component has to be touched, but it is important to consider that we are in the energy transition, with a lot of changes that can lead to different efficiency impacts not related to the efficiency of the network itself and that involve a mix of regulation, technical system and market rules.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

It is important to link the two pillars related to energy efficiency: the Efficiency Directive and the market design guidelines, which are both influencing the contribution of network to energy efficiency. Furthermore, a "stick and carrot" system for network operators, rewarding good efficiency performances and penalizing losses, certainly could help in increasing the awareness of DSOs, which is not very high today.

5.6 Francesco Careri, Policy Officer - Infrastructure and Adequacy at European Union Agency for the Cooperation of Energy Regulators (ACER)

DISCLAIMER: The information and views described in this interview are those of the author and cannot be considered as an official communication or position of the European Union Agency for the Cooperation of Energy Regulators.

- Which are the most promising actions you have in mind for the increase in the efficiency of electricity networks ? Which is the role played by transmission and distribution respectively?

The concept of energy efficiency proposed in this analysis focuses mostly on the physical losses of the grid.

Regarding this aspect, as far as European transmission systems are concerned, losses are limited (accounting for about 2%), mostly technical and difficult to reduce. In other countries outside the EU, where very long transmission lines are present, the issue could be more relevant, there are technological measures – as example, AC to HVDC lines in several cases – that can be implemented to reduce losses. For distribution systems, the voltage control could help, as better voltage profiles could result in lower losses.

Actions like possible interventions in terms of infrastructure assets (high efficiency transformers on the transmission/distribution network, superconductivity wiring, etc.) do not seem currently as a relevant option, at least in the short term. For instance, superconductivity is a solution still not commercially available. In the long term, if the transmission network system will be shaped as supergrids (electricity highways) with long lines connecting, for example, generation hubs in the North Sea and in the Scandinavian area or in Southern Europe (for solar power) with the load centres in Central Europe, these ideas could play a role. However, this is only one possible future evolution of the European power system in the very long-term. Another future could be an evolution towards a more decentralised system, with generation close to the load centres and the integration of a lot of distributed generation, or a combination of both.

It is difficult to foresee what will happen. There could be a combination of different measures taking into consideration the commitments of the single Member States with their NECPs and trajectories that should be followed if the EU Climate Law, as proposed by the European Commission, will be approved.

For high efficiency transformers, substantial improvements are expected to be limited, as transformers are already extremely efficient and significant enhancements in reducing iron losses or copper losses cannot be expected. Investments in transmission network should be performed carrying out a comprehensive cost-benefit analysis and reduction of losses is only one of the main benefits achievable.

- The current regulatory framework is sufficient to ensure the achievement of energy efficiency goals for the transmission and distribution electricity networks, as expected in accordance with the European Energy Efficiency Directive?

Regarding the transmission system, particular changes of regulatory frameworks to increase efficiency are not expected, because – first of all – ensuring efficiency is not the main goal of the regulatory framework. The main goal is to ensure that the proper investments are carried out by transmission network operators in a cost-efficient way and that costs are remunerated in a proper way. As explained above, the benefit of reducing losses thanks to transmission network investments is only one component, and it is not by far the main one.

- According to your opinion, the procurement of energy losses should be under the responsibility of network operators (as it currently happens in the majority of EU Member States) or of suppliers?

The answerer decided to not reply to the question.

- In general, it could be more effective to set mandatory regulations or to define incentives for investments, in order to support network operators in reducing network losses?

The priority should be to develop a consistent regulatory framework, which is quite stable and thus allows network operators to perform investments. Moving towards regulatory practices that take into consideration the full economic life cycle of the asset (TOTEX approach) could contribute in reducing losses because the latter are part of the OPEX.

- The analysis of current regulatory practices related to the losses in transmission or distribution networks shows that, currently, incentives in almost all Member States apply only to DSOs and that 3 main mechanisms can be identified:

  - Incentive-based regulatory models, where the cost of losses is part of the general revenue cap (losses are treated like any other cost component)
  - Allowed rate of losses to include in tariffs capped to a maximum percentage value
  - Mechanisms allowing the network operator to be rewarded (or penalised) if network losses are lower (or higher) than a predetermined reference value

According to your opinion, which is the best one and why?

The answerer decided to not reply to the question.

- According to your opinion, which could be the tariffs design that leads to the most positive impact on the reduction of network losses?

The answerer decided to not reply to the question.

- The current regulation related to electricity and gas could allow an effective cross-sector integration among them, in a future perspective, in order to enhance the energy system flexibility? If no, which changes could be required?

For what concerns transmission, which is the main focus speaking about cross-sectoral integration, evidence shows that integration is not enough. However, it has to be underlined that a review of the TEN-E Regulation is going to be performed this year; so the current framework is expected to change soon. In particular, ACER is in the process of providing to the European Commission elements on how the TEN-E Regulation may be improved to allow cross-sectorial collaboration.

- From a technical point of view, which could be the best actions to be implemented for maximising the increase in electricity network efficiency keeping a balance between investments and economic savings deriving from losses reduction?

As said before, in many cases the economic savings deriving from loss reduction in transmission systems are negligible. Moreover, a better usage of the transmission asset, which is a sort of efficiency, may result in several cases with an increase of losses (e.g. higher flows on a transmission line). Performing a cost-benefit analysis just focusing on reducing losses and on the improvements given by losses reduction, could result in a not viable project in many cases, at least in transmission system. It is important to consider the economic savings deriving from all the different benefit indicators (increase in security of supply, increase of social welfare, etc.). In fact, comparing different options, the same benefit could be achieved in different ways: for instance, by building new power lines or by investing, as example, in

Dynamic Line Rating. In this last case, the benefit on losses could be negative, because with a Dynamic Line Rating it is possible to have higher losses. As said before, considering the whole set of benefits that investments in transmission network may bring, it can be observed that losses are just one component, and not the most important one in several cases.

- Which good practices and recommendations the European Union should introduce in order to build a common framework for all the Member States?

For what concern infrastructure regulation, output-based approaches linked with benchmarking of current efficiency (defining proper metrics in terms of efficiency of network operation) are a possible good option. The aspect is however not only at the European level but also and especially at the national level: the results of such EU good practices and recommendations are therefore linked to the level of reception and implementation at national level.

6 ELECTRICITY AND GAS INTERACTIONS

The interrelations between electricity and gas are becoming more and more important and it is expected to be crucial in the next decades

- From one side, these two commodities can be seen as competitor in the framework of the so-called energy transition towards decarbonisation of energy and economic systems: in this context, the high ratio between the electricity price and the gas price is considered one of the most relevant barriers to the electrification of the energy final uses [22]

- From the other side, these commodities can instead be integrated: in fact, the so-called supply-side sector-coupling (or "cross-vector integration") among them is considered one of the strategies that can relevantly enhance the flexibility of energy systems and allow the achievement of decarbonisation goals in a more cost-effective way, reducing the total costs related to the energy transition

A possible link between the electricity and gas sectors is represented by the implementation of the Power-to-Gas (PtG) technologies, which can be used to produce synthetic methane or hydrogen using electricity (from renewables, in a decarbonisation perspective), when it is available at low prices. The generated gas can be stored in the short term by means of the gas infrastructure (linepack) and, if necessary, reconverted into electricity (Gas-to-Power). The use of PtG when there is an excess in electricity supply eliminates the need for curtailment of renewable electricity generation or the need for additional investments in electricity transmission, distribution or storage infrastructure. This cross-vector integration can also be helpful in effectively addressing seasonal fluctuations in energy demand. In fact, in widely electrified energy systems like those that can be forecasted according to the energy transition, a sufficient electricity supply should be ensured to fulfil the additional demand for heating during cold periods. This will require relevant storage or additional electricity generation capacities, and the existing gas storage capacity can be exploited for this aim. The stored gas can be then reconverted into electricity. However, it has to be underlined that the overall conversion process leads to quite low efficiency values [24], [25]. For instance, the conversion chain from power to power (production of hydrogen from electricity through electrolysis, hydrogen storage, electricity generation from hydrogen through fuel cells) is characterised by an energy efficiency lower than 40%. If hydrogen is produced for blending into natural gas pipelines and then used for producing electricity by means of gas turbines, the efficiency further reduces to values lower than 25%. Furthermore, according to Bompard et al. [26], also the long-distance transportation of energy as electricity through HVDC is more convenient that the transport through gas pipelines: the use of HVDC ensures at the consumption point more than 98% of primary energy, while the adoption of the power-to-gas technology and the consequent use of gas pipelines reduces this value to 44%. Moreover, if the gas is converted again into electricity this chain allows to exploit only 25.5% of the primary energy source. Eventually, even if PtG could be a significant option in order to enhance flexibility in future energy systems, it will be economically sustainable only if it can be operated with a high load factor, and not only to exploit the electricity supply excess, due to the high technological investment costs.

According to a study commissioned by the European Parliament's Committee on Industry, Research and Energy [23], the cross-vector integration between electricity and gas, however, has to overcome several barriers in the short and mid-term. These barriers can be both

- technical-economic:

related to the technologies (materials, costs and performances), to the availability of resources and infrastructures and to the market conditions

- policy and regulatory:

related to the planning and operation of integrated energy systems, to the climate and energy policies and to the market design (including network tariffs).

Focusing on policy and regulation, one of the key aspects is represented by the lack of integrated planning and operation practices, which should cover the entire energy chain (from supply to demand), all the energy commodities and all the scales (from local to European). Integrated planning and operation of energy infrastructure, in particular, should consider the interrelationships between the electricity, gas and heat sectors, in order to assure that new investments are reasonable even in a long-term perspective

Climate and energy policies, which are the first driver of electrification in Europe, as highlighted by Eurelectric [27], are another crucial element. Energy policies should be consistent and provide suitable incentives for the development of flexible decarbonised energy systems. One of the key aspect is, in fact, represented by efficient GHG emissions reduction policies and carbon pricing mechanisms, that could be implemented as reform of the EU emission trading scheme (ETS) or as carbon tax. The EU ETS currently covers only power generation and industry sector, while the building, transport and agriculture sectors are not included, even if some Member States have introduced carbon pricing for non-ETS sectors; this underlines the need for a more coordinated approach, based on a similar CO_2 taxation for all energy commodities and sectors

The market design is another crucial barrier. In particular several studies [28],[29] underline the need for modify the present regulation related to gas transmission, distribution and storage, adapting revenue regulation (capital cost, asset valuation, depreciation, project-specific rules), taking into consideration the role of network operators in storage, and enhancing incentives for innovation

Furthermore, the Trans-European Energy Networks (TEN-E; aiming at ensuring a better interconnection of electricity and gas infrastructures across national borders) and the Connecting Europe Facility (CEF; a funding instrument aiming at promoting the development of high performing, sustainable and efficiently interconnected trans-European networks) mechanisms could be reformed, according to the new European investment priorities, such as infrastructure investments to facilitate the deployment of renewable gas and electricity, which would enable sector coupling

The structure of tariffs for grid connection and access has been identified as another element that can act as enabler or barrier for the coupling between electricity and gas. Depending on the tariff methodology, grid tariffs for energy storage or local injection of renewable electricity or gas can facilitate or penalise it: in particular, tariffs should be cost-reflective and technology-neutral, and should take into account the effects on grid operations arising from the injection of gas or electricity from local producers or storage facilities. For instance, considering the grid tariff schemes for storage, it can be observed that if storage operators have to pay grid charges for both the injection an withdrawal phases, storage becomes less competitive compared to other flexibility options. While the network code on harmonised transmission tariff for gas [30] sets measures to address the double charging issue, there are not similar measures for electricity

Moreover, energy prices are not currently integrating all external costs, and consequently do not incentivise the most effective energy use and investment choices. Electricity prices are still regulated in several Member States, and do not reflect wholesale prices. Energy retail prices should not be fixed by authorities but should rather reflect wholesale prices, and surcharges or subsidies may not alter the competition among energy commodities and should address positive or negative externalities and policy targets. In this sense, the above mentioned implementation of proper carbon pricing could represent a way for making energy prices more cost-reflective and to reduce market and competition alterations [23]

Appropriate rules and liquid markets with adequate time granularity should be set for reserve capacity and balancing energy (possibly at supra-national level) for ensuring the same conditions for various flexibility solutions to participate in these market segments [23].

7 DISCUSSION

7.1 Regarding network tariffs:

Distribution tariffs are the charges levied mostly by DSOs to distribution grid users to compensate their costs. National remuneration mechanisms define the total income of DSOs from these tariffs. Setting or approving distribution grid tariffs is done by National regulatory authorities (NRAs)

Historically, tariffs were applied to consumers according to the consumed volume (volumetric charges) to reflect the user's imposed costs to the grid. However, the introduction of prosumers made this tariff regulation more complicated, as the consumers' costs imposed on the grid are less linked to the consumed volume. For instance, the users which have distributed generators such as PV panels and are close to self-sufficiency in terms of average consumed volume from the grid, are not necessarily imposing low cost on the grid, as long as they stay connected to the grid. The main deficiencies of this tariff structure are: 1) to lead to discrimination as users are not paying the cost they inflict on the grid but socialize them with other users, and 2) not providing economic signals to consumers reflecting their costs to the network, which does not lead users to behave in an efficient manner [15]

Several countries are using time of use distribution tariffs for non-domestic consumers with daily (night/day) or seasonal structure;

Regarding the design of future EU-wide tariffs, all the EU stockholders agreed that the future tariffs design should ensure cost-efficiency and a fair distribution of network costs, including losses, among grid users;

According to the EU guidelines, the goals for designing grid tariffs are: cost reflective, transparent and understandable, economically efficient (incentivizing behavior that maximizes social welfare), economically sustainable (covering infrastructure costs), non-discriminatory, and stable;

In general, tariff structure can have 3 elements:

- volume element (euro/kWh),
- capacity element (euro/kW),
- time element.

Volume element is simple and promotes energy efficiency but does not reflect the drivers of distribution costs. Capacity element has the potential to fully cover the DSOs costs but provides less incentive for energy efficiency for consumers. Finally, time element encourages demand response but is more complex to implement [15]

In [17], most common components of electricity distribution tariffs are presented as:

- Fixed component (also known as standing/service charges by connection point),
- Capacity component (to charge users for the availability of network infrastructures to use a maximum power),
- Active Energy components (volumetric component, also known as variable/commodity charge which charges based on the actual energy usage),
- Reactive energy/power component,
- Loss energy component.

In most countries losses are included in the active energy component.

According to the energy efficiency directive, distribution network tariffs should not prevent: load shifting from peak to off-peak hours by customers, energy savings from demand response of DGs or aggregators, demand reduction from energy efficiency measures undertaken by energy service providers, connection of DG at low voltages, connection of DGs closer to the consumption, and the storage of energy.

7.2 Regarding DSOs' remuneration schemes:

Traditionally, the bottlenecks of the distribution networks are alleviated by the DSOs through expanding the grid, which is not the most efficient option. As a more cost-efficient option, it has been suggested to harness flexibility from grid users (prosumers or regular generators). However, the remuneration scheme of DSOs is typically incentivizing the traditional grid expansion over the more efficient flexibility service provision option [15];

Traditional nature of DSO remuneration schemes were designed based on providing incentives for grid investment (CAPEX). However, going forward, a larger share of costs related to the distribution networks will be outside this regulated cost base. So, the DSOs would not be able to cover their expenses on such efficient activities, while having more incentives to take traditional less efficient solutions of expanding network capacities;

Currently regulators provide several methods for treating losses in transmission and distribution networks:

1) Incentive-based regulatory models where losses are treated like any other cost components and their cost is part of the general revenue cap,
2) allowed rate of losses in the tariffs where a maximum rate of losses which can be covered by network tariffs is determined, and
3) reward/penalty mechanisms allowing network operators to gain/loose profit if their network losses is higher/lower than a predetermined threshold [4]

7.3 Regarding the Energy Efficiency Directive:

"This Directive establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20% headline target on energy efficiency"

Member states shall ensure that concrete measures and investments are identified for introduction of cost-effective energy efficiency improvement action on network infrastructures; (Implementing the Energy Efficiency Directive – Commission Guidance COM(2013) 762 final – 3.7 Guidance on Article 15);

Member states are asked to remove those incentives in transmission/distribution network tariffs that are adverse for the overall energy efficiency, including those that might prevent the participation of demand response in ancillary services market; (EED, 2012/27/EU – Art. 15.4);

Member states should ensure that network operators are incentivized to improve energy efficiency in the design and operation of their infrastructures; (EED, 2012/27/EU – Art. 15.4);

The energy efficiency directive has special focus on enhancing the application of high-efficiency cogeneration and district heating and cooling systems in the union. The member states should carry out comprehensive assessment on the potential for these technologies (EED, 2012/27/EU – Art. 14.1).. These assessments should provide information to the investors and contribute in a stable and supportive investment environment; Moreover, access to the grid and dispatch of electricity from high-efficiency cogeneration should be prioritised (EED, 2012/27/EU – Art. 15.5);

Due to the important role of demand response programs on energy efficiency [31], member states should ensure that national energy regulatory authorities are able to assure that network tariffs and regulations incentivize energy efficiency improvement and support dynamic pricing for demand response measure (EED, 2012/27/EU – Recital 45; Art. 15.1).

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8 RECOMMENDATIONS AND CONCLUSIONS

The current evolving paradigm, driven by the energy transition towards decarbonisation of energy and economic systems, causes the need for an evolution of the regulatory framework, that is expected to become more complex and articulated, also taking into account the leading role that could be played by distributed generation from RES. In this sense, supporting actions for the implementation of more flexible local RES-based energy systems (smart/micro-grids), able to exploit locally available resources, could be promoted, for instance through cost-reflective tariffs for prosumers and incentives for the aggregation into energy communities. This is coherent with what included in the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, which states that "the move towards decentralised energy production has many benefits, including the utilisation of local energy sources, increased local security of energy supply, shorter transport distances and reduced energy transmission losses. Such decentralisation also fosters community development and cohesion by providing income sources and creating jobs locally" (recital 65), and that "small-scale installations can be of great benefit to increase public acceptance and to ensure the rollout of renewable energy projects, in particular at local level. In order to ensure participation of such small-scale installations, specific conditions, including feed-in tariffs, might therefore still be necessary to ensure a positive cost-benefit ratio, in accordance with Union law relating to the electricity market" (recital 17) [32].

These supporting action should also focus on incentivise the digitalisation, which is a key pillar for ensuring penetration and operation of local-scale smart systems, in order to ensure the needed integration of ICT solutions and the investments devoted to prevent and counteract possible critical issues, like those related to cyber security. Regarding this last aspect, the Directive (EU) 2019/944 on common rules for the internal market for electricity and amending Directive 2012/27/EU underlines that "the security of the smart metering systems and data communication shall comply with relevant Union security rules, having due regard of the best available techniques for ensuring the highest level of cybersecurity protection while bearing in mind the costs and the principle of proportionality" (Art. 20(b)) [33].

In this context, also the normative approaches to support the increase in energy efficiency of electricity network has to adapt to be really effective. In this sense, the Directive (EU) 2019/944 highlights that the "regulatory authorities should ensure that transmission system operators and distribution system operators take appropriate measures to make their network more resilient and flexible. To that end, they should monitor those operators' performance based on indicators such as the capability of transmission system operators and distribution system operators to operate lines under dynamic line rating, the development of remote monitoring and real-time control of substations, the reduction of grid losses and the frequency and duration of power interruptions" (recital 83).

Different approaches could be implemented, and – even if it is important to ensure an harmonization at EU level, also considering the expected evolution towards more integrated systems, not only at transmission level but also at distribution level – it is necessary to take into consideration that the different situations that currently characterise the single countries require ad hoc solutions, customized on their peculiarities, more than a general unique regulatory framework to be applied in all the EU Member States. In synthesis, the EU should provide reference guidelines more than strict regulations.

First of all, a revised Energy Efficiency Directive, the regulation could include both mandatory elements and incentives. Some mandatory technical requirements for the grid, like the substitution of existing transformers at the end of their technical life with high efficiency ones, are surely necessary in order to intrinsically reduce the energy losses in the network. The mandatory requirement can be enforced with reference to the enforcement of technical standard on both components (e.g. high performance transformers) and design procedures (e.g. minimum total cost of wiring including cost of losses). However, the best option for enhancing energy efficiency is probably to set incentives, especially to DSOs for pushing the implementation of efficiency improvements; conversely, disincentives for non-efficient network could also be introduced, in order to further encourage DSOs to act.

DSOs should remain the key actors in charge of the procurement of network losses, as they are the only entities able to operate on the efficiency of the grid in a proper way, with respect to both technical and non-technical losses.

Among the different possible approaches to incentive-based regulation, the inclusion of the cost of losses as a part of the revenue cap, treating losses as any other cost component and considering them as a controllable cost, seems more effective in inducing DSOs to make the effort – in a transparent and verifiable way – for increasing the net efficiency.

Of course, the costs of distribution losses should be defined and set taking into account the current status (in terms of type of prevalent losses, level of losses and historical trend), i.e. on the basis of DSOs' past performances with individually established incentive goals.

When the target level of losses is achieved, the incentives for decreasing losses should be concluded and any further action aiming at their reduction should be based on cost-benefit analyses and overall cost effectiveness of the considered measures.

Even if this mechanism could be, in general, identified as the most promising one in pursuing the efficiency goal, according to the previously underlined need for a tailored regulatory approach at single country level, other mechanisms – like the introduction of rewards/penalization for DSOs depending on the amount of losses with respect to a given reference value or the introduction of a maximum percentage of allowed losses to be included in tariffs – can be set.

From the technological point of view, the experimentation of cutting-edge technologies – able to support the efficiency enhancement of the grid – has to be supported and promoted, also through the introduction of regulatory sandboxes. After the experimentation phase, however, a coordination of the possible implementation of these cutting-edge technologies at European scale will be necessary, in order to avoid the development of a grid divide, leading to the coexistence, in the EU, of two types of networks: a high-performance innovative grid and a low-efficiency traditional grid.

The optimal development of the grid should be considered as a key aspect also in the framework of the possible integration between gas and electricity, and specific cost-benefit scenario analysis has to be preventively performed in order to explore the feasibility of new technological solutions like the Power-to-Gas one.

Regarding the current Energy Efficiency Directive, amendments can be implemented, with a special reference to Art. 15, specifically focused on the energy efficiency of the transmission and distribution networks.

In particular, Art. 15.2, requiring Member States to ensure the assessment of the energy efficiency potential of gas and electricity infrastructures and to introduce cost-effective efficiency improvements in the network, could be revised, stressing more the need for promoting a cross sectorial-integration among the two commodities (and the related infrastructures). In fact, even if this aspect is not directly related to the efficiency of the single infrastructures themselves, the possibility of ensuring – through integration – a higher flexibility of the system, coherently with the decarbonisation goals, is a way for efficiently using the existing networks.

The removal of Art. 15.3 (related to the possibility of permitting components of schemes and tariff structures with a social aim for net-bound energy transmission and distribution), Art. 15.7 (related to the possibility for producers of electricity from high-efficiency cogeneration to issue calls for tender for the work of connection to the grid) and Art. 15.9 (related to the information regarding energy efficiency levels of installations undertaking fuel combustion with a rated thermal input equal to or higher than 50 MW) can be evaluated, as they are less relevant with respect to the overall aim of Article 15; Art. 15.7 could be incorporated in Art. 15.6 (focused on high-efficiency cogeneration).

Moreover, future revisions of the Energy Efficiency Directive should take into consideration (even by introducing ad hoc articles), in the framework of an evolution towards an increasing role of smart, decentralised and digitalised solutions, the effects that the introduction of innovative options like blockchain technology could determine on the development of the energy systems (including distribution infrastructures) and on their operation and overall efficiency.

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List of abbreviations and definitions

ACER - Agency for the Cooperation of Energy Regulators

CAPEX – Capital Expenditure

CEER –Council of European Energy Regulators

DG – Distributed Generation

DSO – Distribution System Operator

EED – Energy Efficiency Directive

EEOS – Energy Efficiency Obligation Schemes

ETS – European Trading System

EV – Electric Vehicle

MS – Member State

NRA – National Regulatory Authority

OPEX - Operational Expenditure

PV – Photovoltaic

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